level ground, the potential energy acquired when the foot is lifted, and the consequent slight loss of heat, is neutralised by the *internal* work necessary to prevent the foot having any actual energy at the moment it touches the ground.

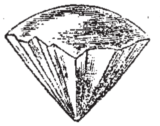
Upon this theory it is clear that the fall of temperature must be greater as the height arrived at is more considerable; and that the body must soon regain its normal temperature when the experimenter ceases to ascend. Lortet's observations agree perfectly with these requirements, he finding that his temperature was normal in less than half an hour after he had reached the summit.

In descending a hill the temperature ought evidently to rise greatly if this explanation is the true one.

A. H. GARROD

St. John's College, Cambridge, December 3

Hailstones



I HAVE frequently observed that when hailstones are large and well formed, they are almost invariably round and smooth at one end, and roughly conical at the other (as in the annexed sketch), so as to suggest the idea that they are broken portions of spheres, of a structure radiating from the centre.

Perhaps some of your correspondents can inform me if there is any proposed theory which accounts for this peculiar form, which should throw some light on the formation of hail.

H. R. PROCTER

Clementhorpe, North Shields

ENCOURAGEMENT TO NATURAL SCIENCE AT TRINITY COLLEGE, DUBLIN

NOTICES have from time to time appeared in this journal of scholarships, exhibitions, &c., obtainable in various colleges at Oxford and Cambridge, for proficiency in the purely Natural Sciences. From these we see that the neglect with which the study of nature has been treated is gradually giving way, and that our great Universities are at last becoming alive to the importance of this branch of learning, and to the necessity for encouraging its pursuit among the students. It is a matter for surprise that no similar mention of rewards for Natural Science is ever made with respect to the University of Dublin. And yet, were a Fellow of Trinity College asked what was being done in this direction at his University? he would probably answer, "Oh, a great deal! there are gold and silver medals awarded at the Moderatorship Examination for Natural and Experimental Science; then there are four or five Science Scholarships given annually." It is true a student may take out his degree with honours in Natural Science, and receives a medal, but let us see what is the course for the so-called Science Scholarships; the subjects are mathematics, pure and applied, for which 350 marks are obtainable, and, as a secondary course, either logic or physics, for which fifty marks alone are given. Such are the rewards and inducements held out to the student of *Natural* Science. It is scarcely to be wondered at that the most promising men in the University do not go in for them, but devote themselves to the more profitable classics or mathematics. For these the rewards are liberal and numerous; there are no less than seventy foundation scholarships, and many others, besides a great number of exhibitions, of which, within the last few months, thirty in addition have been granted by the Board. Not one of these has the man who devotes himself to chemistry, zoology, botany—in short, to Natural Science—a chance of obtaining. We ask—is this fair? Even supposing it unadvisable to divert any of these scholarships or exhibitions from their accustomed channels, yet surely the Board might establish one or two additional ones out of the—confessed to—60,000*l*. annual income.

About a year ago it was rumoured that a "studentship" would in future be given at the degree examination to the first gold medallist in Natural Science, but the idea seems to have died a natural death, and those in whose bosoms a ray of hope had arisen have been doomed to disappointment. It is not to be supposed that the authorities of Trinity College, Dublin, are in any great degree adverse to changes. On the contrary, when a reform (?) is not especially needed, they are not unlikely to introduce it; thus, for instance, the harmless old custom of setting the college clock a quarter of an hour late—giving the students, as it were, a quarter of an hour's law—has been abolished, and the hour for "commons" has been altered.

But we have no wish to lead any one to imagine that an altogether bigoted and unchanging spirit pervades the University: we have much pleasure in saying that many of its institutions are truly liberal; and we can scarcely doubt that before long the governing body will look with more favour on the Natural Sciences, and that they will become aware that Ireland—not so very flourishing at present—will be anything but a loser when the National University sends forth a greater number of scientific men.

A.

THE CONSTRUCTION OF HEAVY ARTILLERY

II.

CHOICE OF MATERIAL

IN an article which appeared on the 24th of last month, we endeavoured to explain the construction of our large ordnance, and to trace briefly the steps by which the combined strength and simplicity of the present pattern in the British service—the Woolwich Gun, as invented by Mr. Fraser—were attained. Simplicity is one chief element of strength; the fewer pieces anything is made of in general the stronger it is, and it has also the advantage of cheapness; but simplicity is seldom the beginning, it is rather the end of a series of inventions and improvements, and this has been the case in gun manufacture.

Having traced the steps of the process, and glanced at the history of its development, one topic more remains to be treated in order to give completeness to the subject, and that is the choice of material; and although the choice of material must come first in actual construction, to know the manner in which the gun is formed, and the qualities sought to be developed in the construction, will be a great help in understanding what qualities it is desirable that the material should possess. There are two qualities between which the choice lies; these are *hardness* and *toughness*. The British Government has decided, we think wisely, in favour of the latter. Hardness is the proper quality to resist a statical force, or pressure; toughness to resist a dynamical force or blow, and the explosion of gunpowder is not only a dynamical force, but it is the greatest that we have to deal with in any mechanical problems. If a hard substance is subjected only to a blow which it is quite able to resist, whose strain is well within the limits of its elasticity, then it is a very fit and proper material for the purpose; and this was the case with the old smooth-bore guns, which were all cast-iron. They were quite strong enough to do with safety all that was required of them. But for the force now imparted to rifled projectiles with their immense range, their tremendous armour-piercing *vis viva*, cast-iron guns are altogether inadequate. Much lower charges than those of our wrought-iron rifled guns would burst them into fragments. Did nature supply us with a material so hard that the strain of gunpowder was easily overcome by it, it would do very well for all guns. If, for instance, diamonds existed of sufficient size that a piece of heavy artillery might be bored from one, then they would be a very admirable material for the purpose. But, as this is not the case, we must fall back on tough instead of hard substances, the more especially as it does not do to approach the limit of resistance, for hard and crystalline substances have often flaws which no inspection can discover, and which only reveal themselves at the moment of destruction, and also such guns, when they burst, always do so explosively, without previous warning. This is not the case with tough material, which can yield through a very considerable extent before breaking. It may be objected that this could be overcome by increasing the thickness of cast-iron guns. But it is found that, after a limit very soon reached, increase of thickness does not produce increase of strength. The following law has been ascertained, that "no possible thickness can enable a cylinder to resist a pressure from within greater per square inch than the tensile strength of a square inch bar of the same material." That is—to take an example—if a cylinder of cast iron, whose breaking strain is ten tons per square inch be subjected to that amount of interior pressure, it will from the very first occasion begin to give way. At first, the inner surface would be ruptured, and the expanding gas or other source of pressure, taking advantage of the fissures, would quickly extend and complete the work of destruction. The inner portions of such a cylinder have much more work to do than those farther out, the same amount of force acting over a greater extent of surface or lamina. It may therefore be roughly estimated that the strains on the successive portions or rings vary inversely as the square of their radii. Dr. Hart, Fellow of Trinity College, Dublin, taking into account the compressibility of the metal, has given the following formula, $\frac{\sigma}{s} = \frac{r^2}{\rho^2} \cdot \frac{R^2 + \rho^2}{R^2 + r^2}$, where s is the strain on the inner surface, σ that on a ring of which ρ is radius, and R and r are external and internal radii of the cylinder. To compare the strains on the inside and outside, let S be the latter, and, as $\rho = R$, the formula becomes $\frac{S}{s} = \frac{2r^2}{R^2 + r^2}$. Applying this to the case of a gun of ten inches calibre, with a thickness of side of five inches, $r = 5$, $R = 10$, and S is to s as 50 to 125, so that more than twice as great a strain is borne by the inner surface as by the outer.

This brings us face to face with one of the great objections to cast-iron guns. In all castings the outer part, which cools first, is stronger than the interior. The metal contracts in cooling, and as the heat first leaves the exterior it first becomes solid, and the inner particles successively unite to it in layer after layer of crystals; so that the centre contains metal but imperfectly coherent. In a casting of two or three feet diameter, a central portion of six, eight, or even more inches in diameter, is found consisting of a spongy mass of scarcely coherent crystals of iron, sometimes with cavities visible to the eye when a section is made. This is exemplified in the annexed drawing (Fig. 1) of a 13-inch sea-mortar shown in section with the head of metal with which it is cast remaining attached, the parts to be cut off and bored out being marked by a black line. The shaded portions represent the weak and porous parts of the metal, which extend down through the centre below the bottom of the powder chamber, where it leaves a soft spot, easily hammered and burnt away by the shock and blaze of the discharge. It is plain that in any piece of artillery thus formed, the strength of the sides must gradually decrease from the exterior to the interior, which is precisely the reverse of what is required. To remedy this the Rodman cast-iron guns, used in the United States, are cast round a core or closed tube, which is inserted in the mould and represents the bore of the proposed gun. Into this tube a stream of cold water is kept continually pouring, so that the molten metal first solidifies round it; and, further, to secure this a fire is kept up round the mould for some time after the casting has begun. Here we have the conditions required in a cast-iron gun, viz. the best and strongest metal in the interior round the bore. Fig. 2 represents a 15-inch Rodman cast in this manner. It will be observed that in its shape, which resembles a soda-water bottle, all angles are avoided and a rounded form carefully preserved. By this another source of weakness is avoided, through compliance with an important law of nature. When any substance solidifies under the influence of heat leaving the mass, "the principal axes of the crystals will always be found arranged in lines perpendicular to the bounding planes of the mass, that is to say, in the lines of direction in which the wave of heat has passed outwards from the mass in the act of consolidation." (The Construction of Artillery, by R. Mallet, M.I.C.E., &c., &c. 1856.) This direction is that of least pressure within the mass, being that of the motion of the heat waves; and the law above stated is part of the far more general principle that in nature the line of least resistance is the one invariably chosen. From this law it follows that wherever there is an angle or sudden change in the form of a casting, through that angle there runs a plane of weakness, arising from irregular crystallization, as the crystals arrange themselves perpendicularly to the surfaces. Every abrupt change in the form of the exterior of a casting, every salient or re-entering angle, no matter how small, upon the exterior of a gun or mortar, is accompanied by one or more planes of weakness in the mass. This was strikingly exemplified in the cylinders of the hydraulic press made for raising the tubes of the Britannia Bridge. The first was made with a flat bottom, consequently it had planes of weakness as shown by the lines VV in Fig. 3, and under the enormous pressure to which it was subjected it gave way, the bottom curving out in the direction of those lines. The second cylinder was made with a rounded bottom, as in Fig. 4, and successfully resisted the pressure to which it was exposed. Cast-iron guns give evidence in bursting of planes of weakness in accordance with this law. The usual lines of fracture are shown in Fig. 5. Any visitor to Woolwich Arsenal can, by inspecting the cemetery where the guns burst in proof or for experimental purposes are preserved, verify this law of nature from many examples. By the form of the Rodman gun this source of weakness is avoided. It is a cast-iron gun, made on thoroughly scientific principles, in which the material is used to the utmost advantage, and therefore it may justly be compared with the Fraser gun, in which the same thing is done with wrought-iron, to measure the value of two materials. A casting is always cheap compared with a forging; in this point the Rodman has the advantage. But at its best, cast-iron has only one-third the strength of wrought-iron. Consequently the Rodman gun cannot be safely rifled. It fires heavy round shot, but with a range and accuracy greatly inferior to that of an elongated rifled projectile. Its initial velocity is high, but it is not long kept up. At close quarters its *racking effect* upon armour plate would be very severe, but its penetrative power is low. In the extensive experiments made at Shoeburyness in 1868 the 10-inch Fraser gun of 18 tons weight penetrated fifteen inches of iron (in three 5-inch armour plates), upon which the Rodman 15-inch gun of 20 tons only made a shallow indent. Further, being cast-iron, they are liable to burst explosively without any previous indication, and from the metal being in a state of great tension, being cooled from the inside, they have been known to break up in store.

The facts stated in the comparison of the best and most scientifically-constructed cast-iron with wrought, seem to be very decisive against the former. Two other materials have to be noticed. One is bronze, or gun-metal. It has some admirable qualities for making a gun. A bronze gun is hardly ever known to burst under ordinary circumstances. So great is its tenacity that with continued firing such a gun has been known to swell and change form without bursting.

But there are two objections to its use for heavy artillery that are decisive against it:—It is very expensive. The respective cost of guns of the several materials treated of in this paper may be taken in general as stated in the following table:—

Cast-iron guns . . .	£21	per ton	weight of gun.
Armstrong wrought-iron	£100	"	"
" " Fraser construction	£65	"	"
Steel on Krupp's or Whitworth's plan .	£170	"	"
Gun-metal	£190	"	"

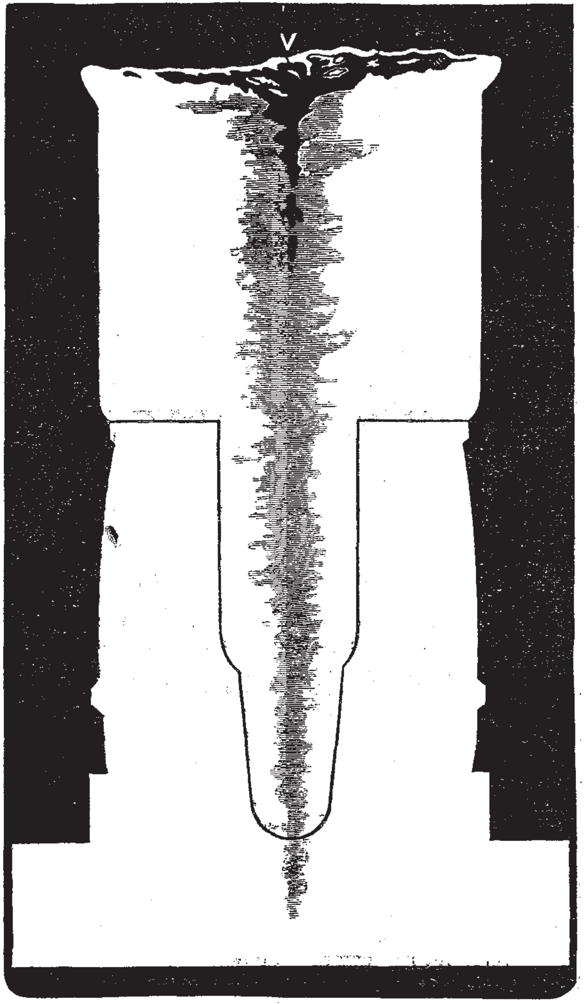


Fig. 1.

But a still more fatal objection to gun-metal for heavy pieces of artillery is its softness, and the rapidity with which it becomes heated. It is therefore quite unfit for the large charges of powder and immense rifled shot, with its severe friction on the bore, which are used in armour-piercing guns. Even small bronze guns, when fired repeatedly, exhibit the curious phenomenon of "drooping at the muzzle." This has been very interestingly explained by Mr. Mallet in the valuable work before referred to, and shown to arise chiefly from the rapidity with which that metal takes up heat. For large guns it is a material out of the question.

The last material to be spoken of is a far more formidable rival to wrought-iron, namely, steel. Of this Krupp's guns and Sir Joseph Whitworth's guns are constructed. The latter are made in a series of cylinders like the Armstrong coils, and which fit very tightly one over the other, and are forced on each other by hydraulic pressure. The former are bored out of huge solid ingots, which have been hammered to give them a fibrous character. Now steel has some admirable qualities as a material for heavy guns. It is very hard; and this makes it very suitable for the grooves of a rifled gun which have to bear such severe friction from the shot. For this reason all our wrought-iron guns are provided with an inner tube of steel. Moreover, it is very strong; the average breaking weight of a bar of steel of an inch sectional area is thirty-one tons, against twenty-five tons for a similar bar of wrought-iron (in the direction of its fibre) and ten tons for cast-iron; and when toughened by being tempered in oil the breaking weight rises as high as forty-five tons to the square inch. The reason why steel is so much stronger when tempered in oil instead of water, is, that the boiling point of oil is so high (600° F.) that it withdraws the heat very slowly from the red-hot mass plunged into it, compared with water, which is turned into vapour at 212° F. The steel for the tubes of the Woolwich guns is always thus tempered. But though steel has these admirable qualities as a material for heavy artillery, there are very grave objections to its use, and, on the whole, good reasons for preferring the wrought-iron guns to any steel ones that have yet been made. One is the greater cost, as shown in the table given above. A much stronger reason is, that though steel bears a gradual pressure so well, such as that of a testing machine for the breaking weight, it is brittle under a very severe dynamic strain or blow. When a steel gun bursts, it does so explosively without previous indications of yielding, and breaks up into fragments like a cast-iron gun. Another objection, and one perhaps even still more weighty, is that it is very difficult to make steel in large masses homogeneous throughout, and free from flaws. It is very much a chance whether it is so or not; and in the case of a gun, this is determined by the fact of its not bursting in service, but cannot be settled by a few proof shots beforehand. A good steel gun is a weapon of wonderful power and very great endurance. But one apparently exactly the same, and made in the very same way, in fact a twin gun, may burst before the hundredth round, or even at the first or second. From time to time, inventions of some process to make steel cheaply and of a homogeneous texture are announced. When some such announcement passes into realisation, it will be time for our Government to abandon a system which arms the country with guns at a moderate price, of a power which weight for weight is not surpassed by those made on any other system, and whose endurance may after proof be relied upon. Our gunners have no reason to be afraid of their own guns. Many of the continental Governments have been supplied with Krupp's steel guns, but very frequently they have burst in an unceremonious and unsatisfactory manner. On one occasion, the director of the Artillery Depôt at Tegel, near Berlin, was killed by the unexpected bursting of a steel 4-pounder gun. The manner of manufacture shows that steel is not calculated to bear a high dynamic strain. At the great gun factory at Essen the steel is hammered with steel hammers of immense weight, as much as 50 tons; but they are single action hammers, lifted up by steam, and allowed to fall by their own weight.* The 12-ton hammer used for forging our wrought-iron guns, which is driven down by steam power, has much greater dynamic force than the far heavier ones with which Krupp forges his steel. But the steel would break and crumble under a swift blow.

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* The greatest achievement of Krupp's Gun Factory is a fifty-ton gun to fire a 100lb shot, which he presented to the King of Prussia; a fitting present to make a monarch. It cost nearly 10,000*l*., and occupied ten months of labour, night and day, in its manufacture. It was exhibited at Paris in 1867. Alas, that it should now return there under far different circumstances! But the manner of its construction cannot claim the merit of high scientific principles. A steel tube was formed sufficiently strong to resist the discharge; but as this would be so light that the recoil would hurl it into the air, like the toy cannons of our boyhood, it had shrunk round it enormous cast-iron rings or tubes. This was metal used for weight and not for strength. Whereas, the scientific principle very fairly laid down by the late Captain Blakely, R.A., is that "a gun should, if possible, be constructed in such a manner that each part of its mass would do its due proportion of work at the instant of firing."

From what has been stated, it will be understood that the wrought iron now used for our guns, which was adopted upon Mr. Fraser's recommendation previous to his invention of our present system of construction, is of a soft and cheap character, instead of the hard, steely iron, which is much more expensive, and of which the guns were formerly made. The bars for coils are made in the Royal Gun Factories from scrap-iron, and from the stock of obsolete cast-iron ordnance. By this a very great economy is effected. Major Palliser has in another way utilised the old cast-iron guns by enlarging the bore and lining it with a wrought-iron and steel tube. The cost of this is about two-thirds of a Fraser gun of the same calibre; but they cannot be equal to a gun made entirely of wrought-iron.

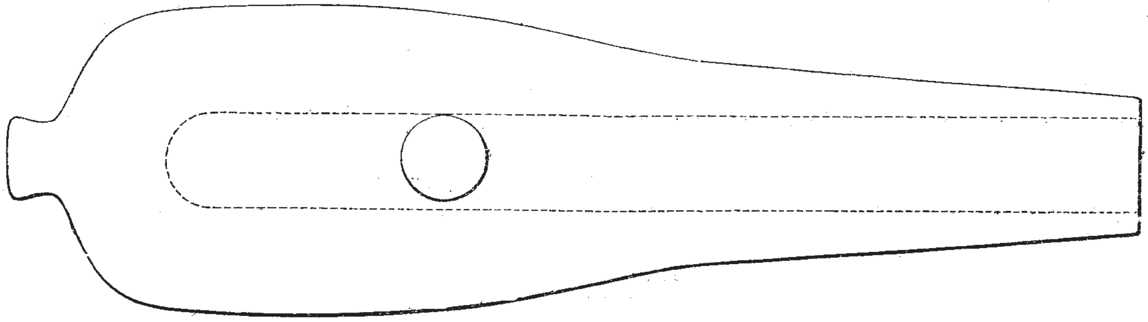

FIG. 2.

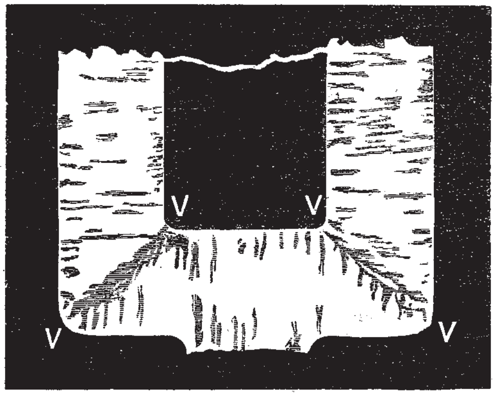

FIG. 3.

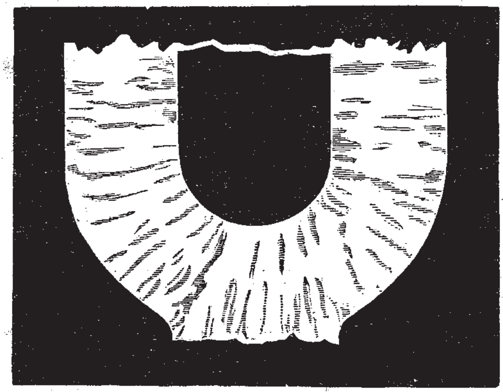

FIG. 4.

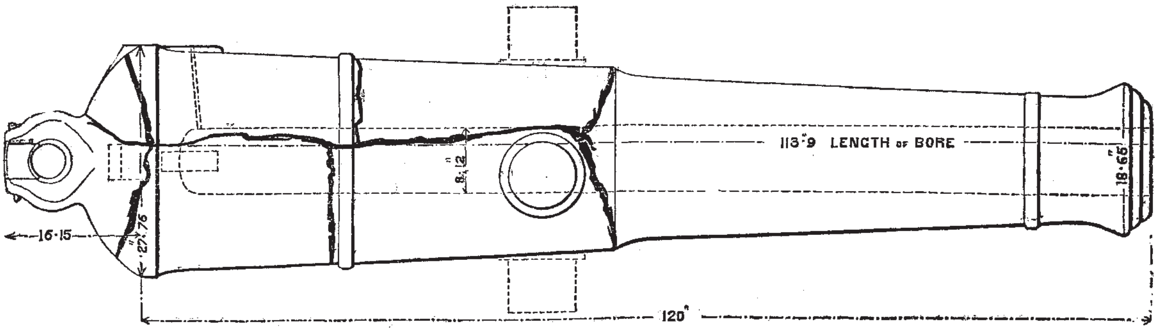

FIG. 5.

In investigating the structure and materials for heavy guns, we see two great powers of nature wrestling before us: the strongest material and the greatest dynamic force, that of explosives, which man can use, and in the struggle some of her more recondite laws are exhibited in action. Each burst gun lying in the *cemetery* has its epitaph (if, we could read it) written by the hand of nature, and telling accurately the cause of death. Those few that have been here deciphered and put together may form, it is hoped, a not uninteresting page in her notebook.

The authorities for most of the statements in this paper are, besides Mr. Mallet's very valuable work before referred to, two exceedingly interesting papers in the Proceedings of the Royal Artillery Institution, by Captain F. S. Stoney, R.A., Assist. Supt. Royal Gun Factories, entitled "A Brief Historical Sketch of our Rifled Ordnance," and "The Theory of Gun Architecture."

NOTES

WE learn by telegraph that the Sicilian section of the Eclipse Expedition, under Mr. Lockyer's directions, arrived safely at Rome on the morning of the 12th; thanks to the capital arrangements made by Mr. Vignoles with foreign railways for the transit of the party. Through carriages for the observers and instruments were taken from Ostend over the Brenner Pass to Verona; and they would have been sent further had not a breakage occurred in passing over the Brenner. The party intended leaving Naples for Syracuse in H.M.S. *Psyche* in the course of yesterday. All the Governments are aiding to the utmost in their power.

WE are glad to be able again to report favourably of the state of both Sir R. Murchison and Prof. B. Stewart. The former has continued to gain somewhat in strength, and the progress of the latter from day to day has been as satisfactory as could be desired.

WE have to announce that Mr. C. L. Bloxam has succeeded the late Dr. W. A. Miller as Professor of Chemistry in King's College, London, and that Dr. Debus, F.R.S., has been appointed Examiner in Chemistry to the University of London, in the place of the late Dr. Matthiessen.

PRESIDENT WOOLSEY of Yale College, U.S.A., has announced his intention of resigning his office. He has been President of Yale for more than a quarter of a century.

L'ABBE MOIGNO has discontinued the publication of his *Les Mondes* owing to the scarcity of paper and the impossibility of sending his periodical to the subscribers. L'Abbé Moigno, however, attends regularly the sittings of the Institute. M. de Parville is now the scientific editor of the *Journal Officiel*, as in former times. He is the only contributor to that paper who has been kept in office, which is highly creditable both to M. de Parville and to the French Government. M. de Parville's contributions are pirated by almost every French paper published in Paris, the only exception being the *Liberté* when M. de Fonvielle was in Paris. Now, *Liberté* must do like others. Reports on scientific matters are published in the *Journal Officiel* with more regularity and space devoted to them than in former times.

M. DECAISNE, Professor of Agriculture at the Museum, has laid before the French Institute, of which he is a member, a scheme for the early growing of cabbages, radishes, &c., &c., which are to be sown in land richly manured, kept for a fortnight, and used stem and root, as a new description of vegetable. This diet is intended to protect Parisians against scurvy when the use of salt beef becomes still more frequent than it is now. The working of this scheme is superintended by M. Toigneaux, the editor of several agricultural papers. Different pieces of waste land close to the walls were appropriated, and vegetables of that description must be now actually on sale.

AS soon as the investment of Paris was completed, the authorities took measures for preventing the destructive effects of shelling. Bills were printed and affixed to almost every house with directions for stopping the fire set up by the bursting of shells. Large tubs, filled with water, were placed on every floor of the large houses and private buildings. Although covered carefully with canvas, the water, having been left for weeks and weeks, became corrupted and fœtid. Proper instructions were given for stopping the infection by the using of charcoal. Two of these tubs are placed in the hall where the French Academy held its sittings, and two others in the *Salle des pas perdus*, by which visitors and members are introduced to it.

M. BARRAL, well known for the part he took in balloon experiments twenty years ago, has volunteered with his son for the balloon service. M. Barral was for many years the editor of the *Presse Scientifique*, a periodical which was discontinued a few years ago.

THE *Société Chimique* continues its sittings, devoted exclusively to warlike, culinary, and sanitary purposes. This body has offered a gun to the Provisional Government. It was built on new principles, and paid for out of the funds of the society, which do not flow out of the national exchequer, the *Société Chimique* being one of the very few French scientific bodies which are not supported by the State.

M. DUMAS is always in earnest for any improvement of diet. He has patronised the use of gelatine obtained from the carcasses of oxen, sheep, and pigs, by hydrochloric acid. The French Institute appears to have reversed the verdict given thirty years ago against the gelatine as proposed by D'Arcet, the only difference being that gelatine is not now prepared by steam, but by the action of acid on animal products, and that a new name, *osseine*, is given to the substance. He has also supported a scheme for grinding the whole of the corn, except the exterior coating, and the making of the flour so obtained into bread. But there is so large a quantity of corn and flour at Paris that the Government, although approving the scientific principles of this new method of grinding corn, declared the suggestion to be useless for the moment.

THE same answer was given to another suggestion, relating to the roasting of the corn for making a kind of gruel called *bouillie romaine*. It appears that this was the diet of the Roman legions, and that the gruel so obtained is very acceptable indeed. A kitchen for public distribution was said to be opened, but Government interfered, thinking, very properly, that it would be good to delay such steps for many weeks. They will use it only if the siege is prolonged so long that there is some danger of actual starvation.

M. BERTHELOT, although not a member of the French Institute, is the president of a standing committee for using scientific discoveries in the defence of Paris. That committee holds its sittings at the Ministry for Public Instruction, of which M. Jules Simon is the head. Many valuable suggestions have been adopted by that committee, which was closely connected with the Committee of Barricades, presided over by Rochefort.

M. JAMIN, the celebrated Professor of Natural Philosophy at the Sorbonne and member of the French Institute, has enlisted as a private in the artillery of the National Guard, and is doing his duty regularly, although begging for a weekly authorisation from the lieutenant in command to enable him to attend the sittings.

THE two Becquerels, father and son, have left Paris, and their place is filled by supernumeraries. Some papers have remarked very sharply upon it, and asked for the discharge of the younger.

THE following notification has been issued from the Home Department respecting the International Exhibition of 1871, dated Simla, October 11, 1870:—His Excellency the Viceroy and Governor-General in Council has been pleased to nominate